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[54] **VALVE TIMING CONTROL DEVICE**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[7] **F01L 1/344**; F01L 13/00

[52] **U.S. Cl.** **123/90.17**; 123/90.31

[58] **Field of Search** .... 123/90.15, 90.17, 123/90.31; 74/568 R; 464/1, 2, 160

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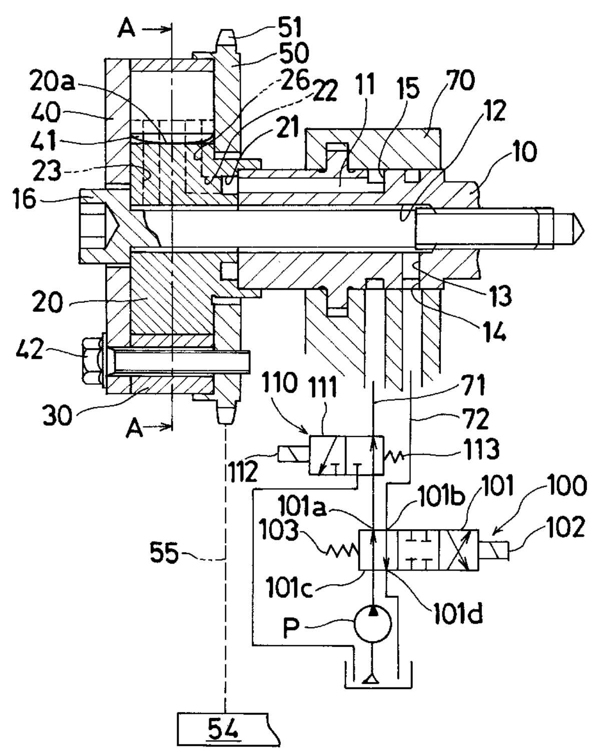
Primary Examiner—Weilun Lo

Attorney, Agent, or Firm—Reed Smith Hazel & Thomas LLP

[57] **ABSTRACT**

A valve timing control device incorporates a rotary shaft rotatably assembled within a cylinder head of an internal combustion engine, a rotational transmitting member mounted around the peripheral surface of the rotary shaft so as to rotate relative thereto within a predetermined range for transmitting a rotational power from a crank shaft, a vane provided on either one of the rotary shaft and the rotational transmitting member, a pressure chamber formed between the rotary shaft and the rotational transmitting member, and divided by the vane into an advance chamber and a delay chamber, a first fluid passage for supplying and discharging a fluid to and from the advance chamber, a second fluid passage for supplying and discharging a fluid to and from the delay chamber, a locking mechanism for holding the relationship between the rotary shaft and the rotational transmitting member at a middle position of the predetermined range, when the internal combustion engine starts, and a controlling mechanism for restricting the rotational transmitting member to rotate around the rotary shaft within a range between the middle position and an end position of the predetermined range.

6 Claims, 4 Drawing Sheets



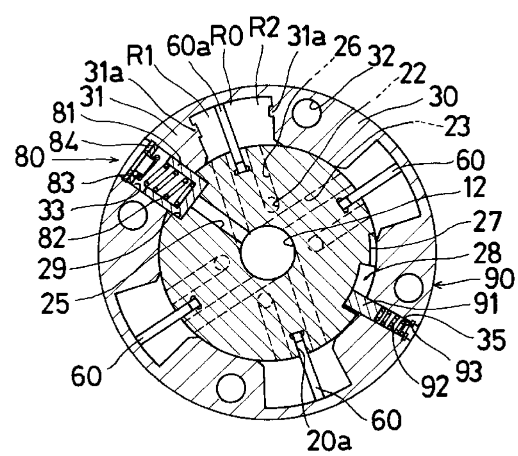
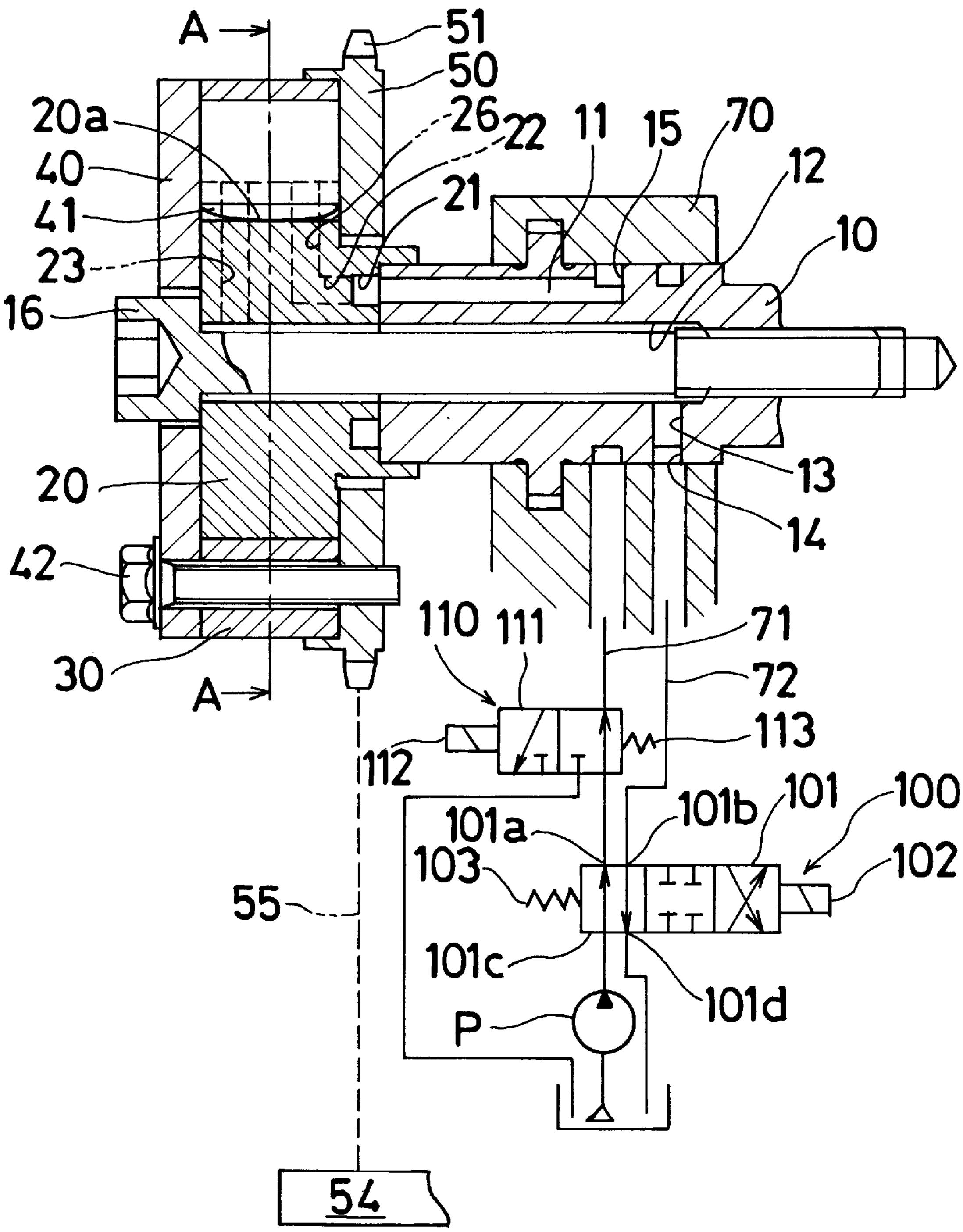


Fig. 1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51
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22
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70
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12
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21
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23
16
13
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14
42
110
111
71
30
72
A
113
112
101
100
101b
101a
102
103
55
101c
101d
P
54

Fig. 2

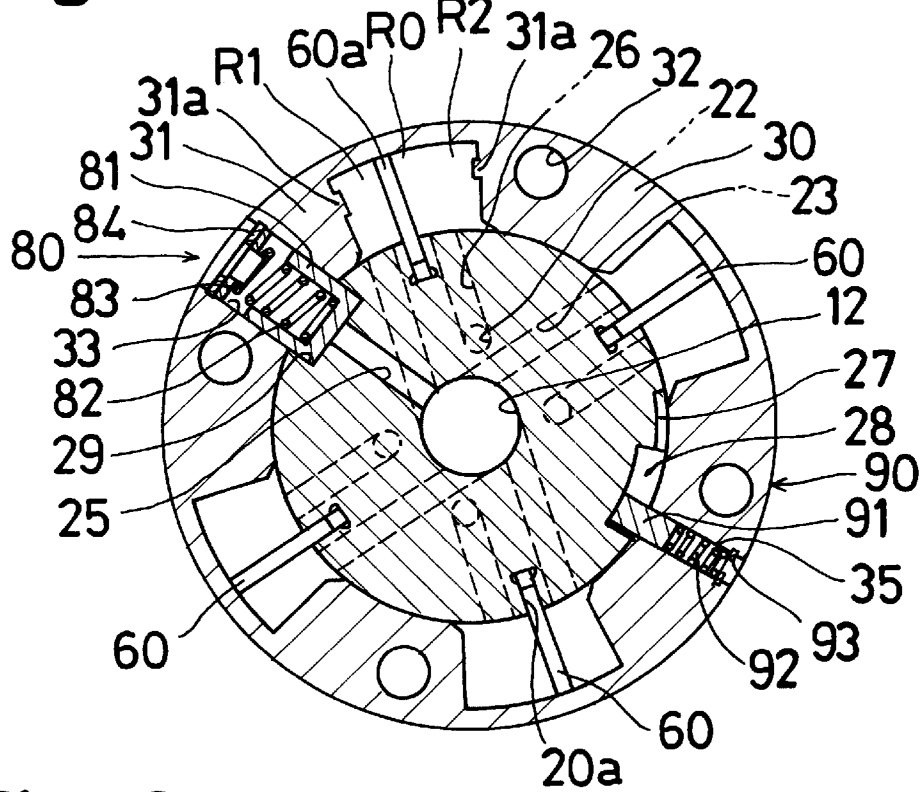

31a
R1
60a
R0
R2
31a
26
32
22
30
23
81
31
84
80
83
33
82
29
25
60
12
27
28
90
91
35
93
92
60
60
20a

Fig. 3

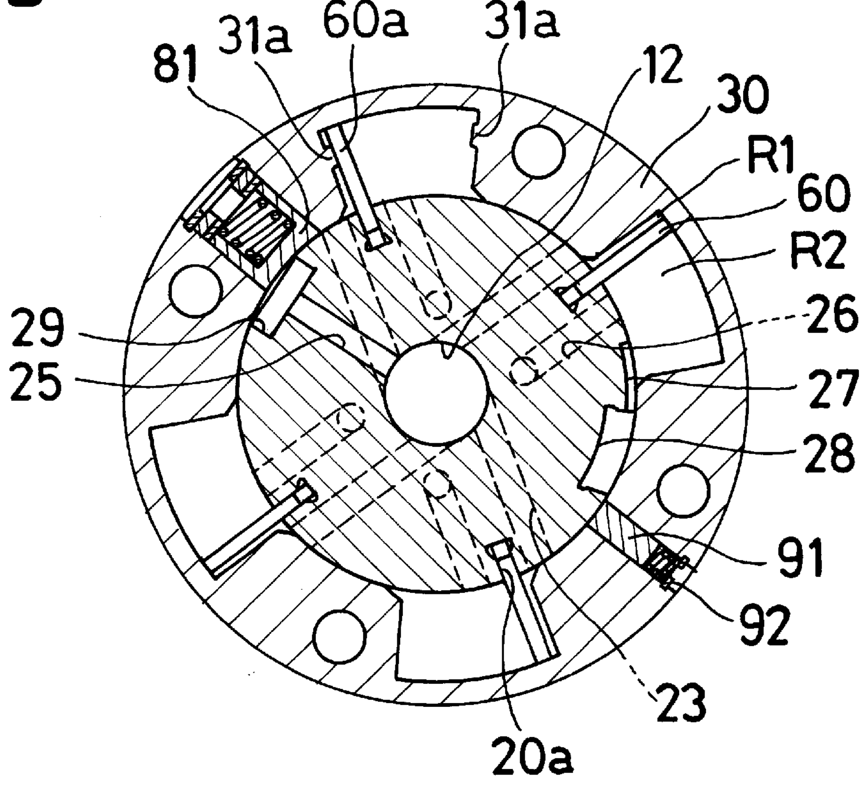

81
31a
60a
31a
12
30
R1
60
R2
26
29
25
27
28
91
92
23
20a

Fig. 4

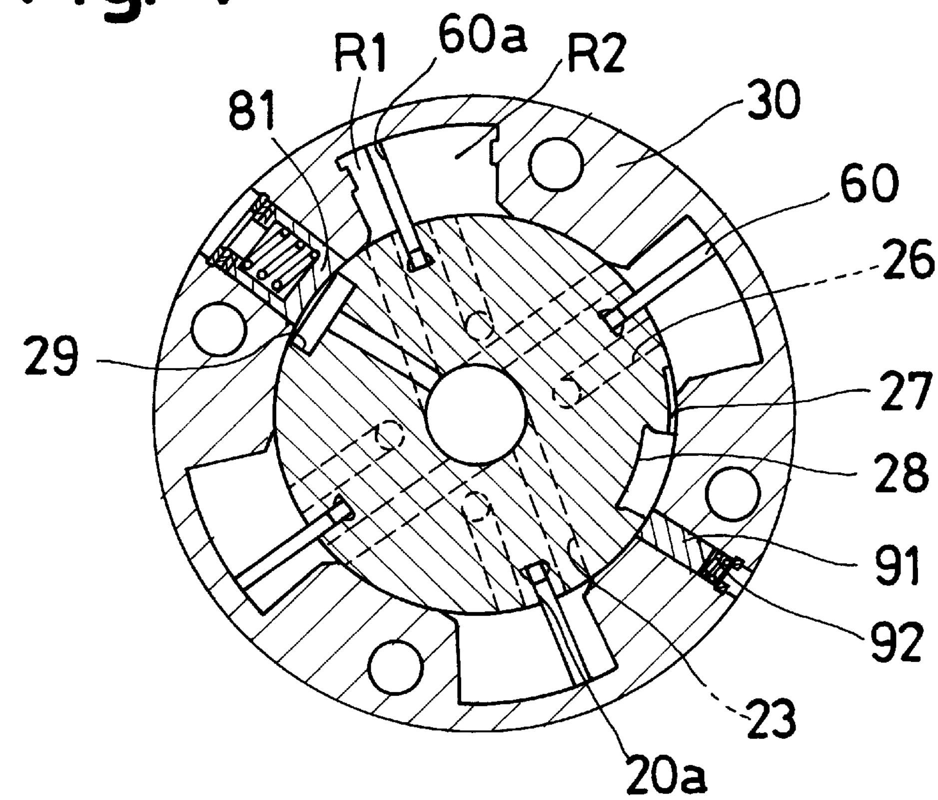

R1
60a
R2
30
81
60
26
29
27
28
91
92
23
20a

Fig. 5

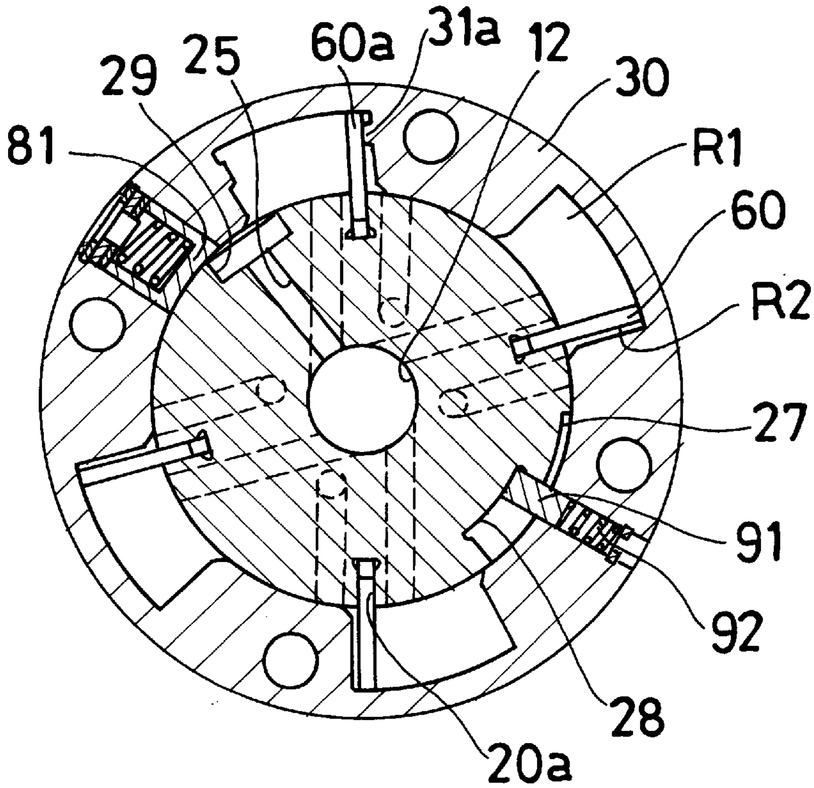
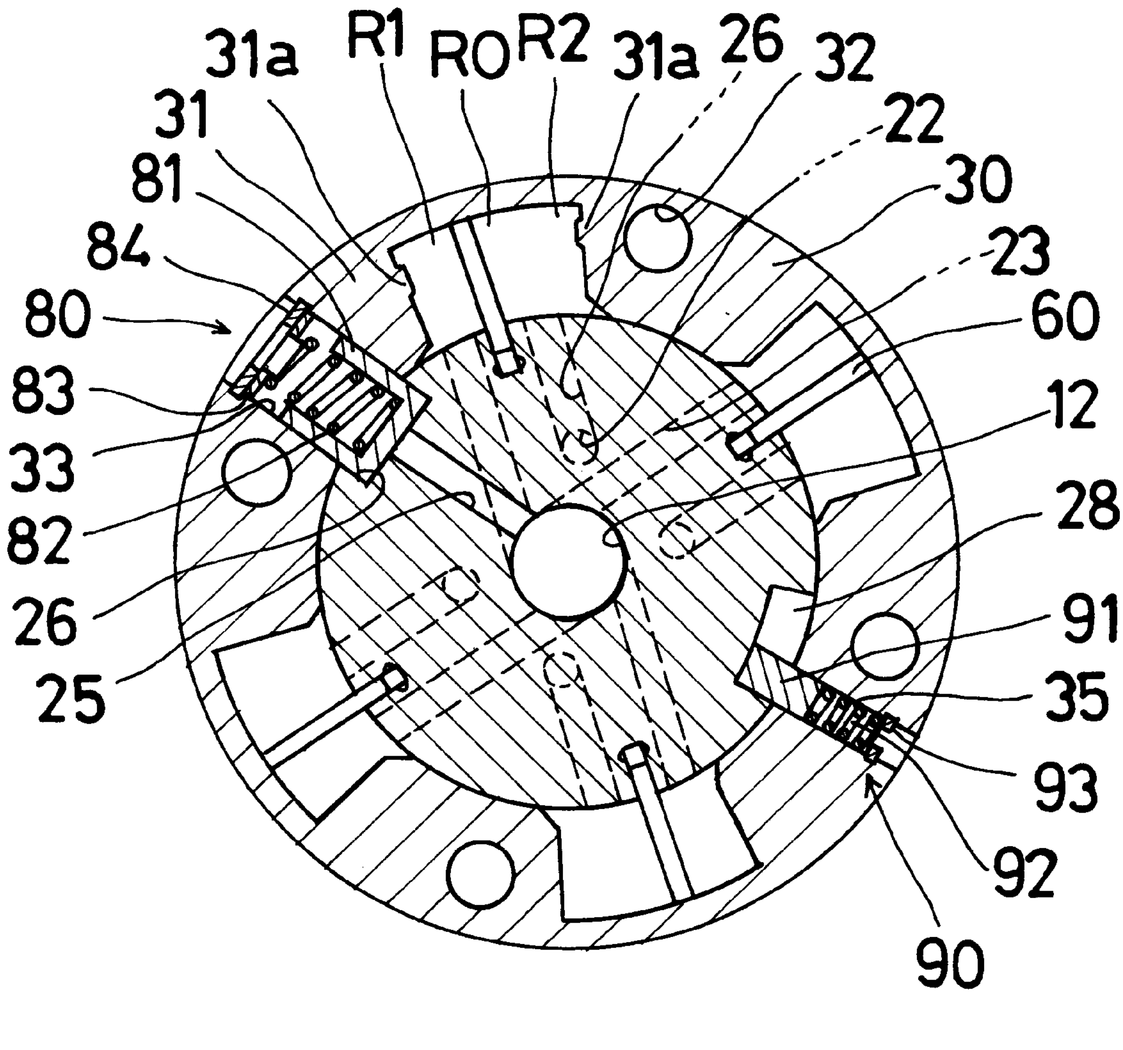

29
25
60a
31a
12
30
81
R1
60
R2
27
91
92
28
20a

Fig. 6


31a
R1
RO
R2
31a
26
32
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22
81
30
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80
60
83
12
33
28
82
91
26
35
25
93
92
90

VALVE TIMING CONTROL DEVICE

FIELD OF THE INVENTION

The present invention relates to a valve timing control device and, in particular, to the valve timing control device for controlling an angular phase difference between a crank shaft of a combustion engine and a cam shaft of the combustion engine.

BACKGROUND OF THE INVENTION

A conventional valve timing control device comprises: a rotational shaft for opening and closing a valve; a rotational transmitting member rotatably mounted on the rotational shaft; a vane provided on the rotational shaft; a pressure chamber formed between the rotational shaft and the rotational transmitting member and divided by the vane into an advance chamber and a delay chamber; a first fluid passage communicated with the advance chamber for supplying and discharging a fluid; a second fluid passage communicated with the delay chamber for supplying and discharging the fluid; and a locking member for maintaining a relative position between the rotational shaft and the rotational transmitting member. Such a conventional variable timing device is disclosed, for example, in Japanese Patent Laid-Open Publication No. H01-92504 and in Japanese Patent Laid-Open Publication No. H09-250310.

In the conventional valve timing control device, the valve timing is advanced due to relative displacement between the rotational shaft and the rotational transmitting member when the fluid is supplied to the advance chamber and is discharged from the delay chamber. On the contrary, the valve timing is delayed due to the counter displacement between the rotational shaft and the rotational transmitting member when the fluid is discharged from the advance chamber and is supplied to the delay chamber.

Further, in the conventional valve timing control device disclosed in the publications, the vane transmits the rotation from the rotational transmitting member to the rotational shaft. Therefore, the rotational shaft always receives a force which expands the delay chamber while the internal combustion engine is running. When the internal combustion engine is stalled, the rotational shaft rotates so as to expand the delay chamber due to lack of enough fluid supply to hold the vane at the current position. Thus, the rotational shaft reaches the most delayed position where the delay chamber is the largest. In case the internal combustion engine is cranked at the most delayed position of the rotational shaft, the vane vibrates due to unstable transitional pressure so as to generate undesirable noise. Conventionally, the locking member maintains the predetermined relative position between the rotational shaft and the rotational transmitting member so that generation of such vibration of the vane is effectively prevented.

Moreover, air intake tries to flow into a cylinder by inertia even after the piston begins to go to the top dead center while the internal combustion engine is running at high speed. Therefore, volumetric efficiency may be improved by delaying closure of an air-intake valve so that the output of the internal combustion engine may be improved.

However, in the conventional valve timing control device, the most delayed position has to be set so that the air intake is sufficient to crank the internal combustion engine. This means that the closing timing of the air-intake valve is not optimized for the high-speed operation of the internal combustion engine. Thus, the volumetric efficiency cannot be improved by the inertia of the air intake. If the closing timing

of the air intake valve is unreasonably optimized for the high-speed operation of the internal combustion engine, the air intake which is at first inhaled into the cylinder flows backward upon start of the internal combustion engine since the air intake does not have enough inertia and the air-intake valve continues to be opened even after the piston passes the bottom dead center and begins to go to the top dead center. Therefore, the internal combustion engine becomes hard to crank due to insufficient compression ratio and imperfect combustion. Further, in the conventional valve timing control device, due to low atmospheric pressure, a similar disadvantage may be expected at high altitudes if the air intake valve is set to be closed at around the bottom dead center of the piston.

Further, in the conventional valve timing control device, if the exhaust valve timing is similarly delayed, the amount of exhaust gas recirculating is increased by an extended overlapping time of the air-intake valve and the exhaust valve so that the internal combustion engine becomes hard to start.

SUMMARY OF THE INVENTION

The invention has been conceived to solve the above-specified problems. According to the invention, there is provided a valve timing control device comprising: a rotary shaft rotatably assembled within a cylinder head of an internal combustion engine; a rotational transmitting member mounted around the peripheral surface of the rotary shaft so as to rotate relative thereto within a predetermined range for transmitting rotational power from a crank shaft; a vane provided on either the rotary shaft or the rotational transmitting member; a pressure chamber formed between the rotary shaft and the rotational transmitting member, and divided by the vane into an advance chamber and a delay chamber; a first fluid passage for supplying and discharging a fluid to and from the advance chamber; a second fluid passage for supplying and discharging a fluid to and from the delay chamber; a locking mechanism, for holding the relationship between the rotary shaft and the rotational transmitting member at a middle position of the predetermined range, when the internal combustion engine starts; and a controlling mechanism for restricting the rotational transmitting member to rotate around the rotary shaft within a range between the middle position and an end position of the predetermined range.

Other objects and advantages of invention will become apparent during the following discussion of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and additional features of the present invention will become more apparent from the following detailed description of embodiments thereof when considered with reference to the attached drawings, in which:

FIG. **1** is a sectional view of a first embodiment of a valve timing control device in accordance with the present invention;

FIG. **2** is a section taken along the line A—A in FIG. **1** when a locking mechanism holds the rotary shaft and the rotational transmitting member at a middle position;

FIG. **3** is a view similar to FIG. **2** but showing the most delayed position;

FIG. **4** is a view similar to FIG. **2** but showing another position between the most delayed position and the middle position;

FIG. **5** is a view similar to FIG. **2** but showing the most advanced position; and

FIG. **6** is a view similar to FIG. **2** but showing a modified version of the first embodiment in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A valve timing control device in accordance with preferred embodiments of the present invention will be described with reference to the attached drawings.

A valve timing control device according to the present invention, as shown in FIGS. **1** though **5**, is constructed so as to comprise a valve opening and closing shaft including a cam shaft **10** rotatably supported by a cylinder head **70** of an internal combustion engine, and an internal rotor **20** integrally provided on the leading end portion of the cam shaft **10**; a rotational transmitting member mounted around the internal rotor **20** so as to rotate relative thereto within a predetermined range and including an external rotor **30**, a front plate **40**, a rear plate **50** and a timing sprocket **51** which is integrally formed around the rear plate **50**; four vanes **60** assembled with the internal rotor **20**; a locking mechanism **80** assembled with the external rotor **30**; and a controlling mechanism **90** assembled with the external rotor **30**. Here, the timing sprocket **51** is constructed, as is well known in the art, to transmit the rotating power to the clockwise direction of FIGS. **2** through **5** from a crankshaft **54** via a timing chain **55**.

The cam shaft **10** is equipped with a well-known cam (not shown) for opening and closing an intake valve (not shown) and is provided therein with a delay passage **11** and an advance passage **12**, which are extended in the axial direction of the cam shaft **10**. The advance passage **12**, which is disposed around a bolt **16**, is connected to a connection port **101***b* of a control valve **100** via a radial passage **13**, an annular passage **14** and a connection passage **72**. On the other hand, the delay passage **11** is connected to a connection port **101***a* of the control valve **100** via an annular passage **15**, a connection passage **71** and a changeover valve **110**.

The control valve **100** includes a solenoid **102**, a spool **101** and a spring **103**. In FIG. **1**, the solenoid **102** drives the spool **101** leftward against the spring **103** when the solenoid **102** is energized. In the energized state, the control valve **100** connects an inlet port **101***c* to the connection port **101***b* and also connects the connection port **101***a* to a drain port **101***d*. On the contrary, in the normal state, the control valve **100** connects the inlet port **101***c* to the connection port **101***a* and also connects the connection port **101***b* to the drain port **101***d*, as shown in FIG. **1**. The solenoid **102** of the control valve **100** is energized by an electronic controller (not shown). As a result, operational fluid (working oil) is supplied to the delay passage **11** when the solenoid **102** is deenergized, and to the advance passage **12** when the solenoid **102** is energized. Because of duty ratio control of the electronic controller, the spool **101** may be linearly controlled so as to be retained at various intermediate positions. All the ports **101***a*, **101***b*, **101***c* and **101***d* are closed while the spool **101** is retained at the intermediate position.

The changeover valve **110** includes a solenoid **112**, a spool **111** and a spring **113**. In FIG. **1**, the solenoid **112** drives the spool **111** rightward against the spring **113** when the solenoid **112** is energized. In the normal state, the changeover valve **110** connects the connection port **101***a* to the delay passage **11** via the connection passage **71**. On the contrary, in the energized state, the changeover valve **110** closes between the connection port **101***a* and the delay passage **11** and connects the delay passage **11** to an oil pan **105** via the connection passage **71**. The solenoid **112** of the changeover valve **110** is also energized by the electronic controller (not shown).

The internal rotor **20** is integrally fixed in the cam shaft **10** by means of the bolt **16** and is provided with four vane grooves **20***a* for providing the four vanes **60** individually in the radial directions. Further provided are a fitting hole **29** for fitting a top portion of a locking pin **81** to a predetermined extent in the state shown in FIG. **2**, where the cam shaft **10**, the internal rotor **20** and the external rotor **30** are in a synchronized phase (the vanes **60** are in the middle position of a chamber R**0**) relative to one another; a passage **25** for supplying and discharging the operational fluid to and from the fitting hole **29** via the advance passage **12**; four passages **23** for supplying and discharging the operational fluid to and from advancing chambers R**1**, as defined by the individual vanes **60** via the advance passage **12**; a circle groove **21** which communicates with the delaying passage **11**; four connecting passages **22** which are formed in the axis direction of the bolt **16** and each of which communicates with the circle groove **21**; and four passages **26** for supplying and discharging the operational fluid to and from delaying chambers R**2**, as defined by the individual vanes **60** via the delaying passage **11**, the circle groove **21** and the connecting passage **22**. The fitting hole **29** is disposed on the peripheral surface of the internal rotor **20** and is extended in the radial direction of the internal rotor **20**. In addition, there is a connecting groove **28** on the peripheral surface of the internal rotor **20**. The connecting groove **28** is a member of the controlling mechanism **90**. When the locking mechanism **80** prevents the internal rotor **20** from rotating relative to the external rotor **30** as shown in FIG. **2**, a top portion of a connection pin **91** can insert into one end portion of the connecting groove **28**. On the other hand, when the internal rotor **20** with the vanes **60** and the cam shaft **10** are at the most advanced position relative to the external rotor **30**, the front plate **40** and the rear plate **50** as shown in FIG. **5**, the top portion of the connection pin **91** can insert into the other end portion of the connecting groove **28**. In addition, there is a communication groove **27** which communicates between the connecting groove **28** and the adjacent delay chamber R**2**, when the internal rotor **20** and the vanes **60** are at between the middle position and the most delayed position relative to the external rotor **30**, the front plate **40** and the rear plate **50**. Here, each vane **60** is urged radially outward by a vane spring (not shown) fitted in the bottom portion of the vane groove **20***a*.

The external rotor **30** is so assembled with the outer circumference of the internal rotor **20** as to rotate relative thereto within a predetermined range. To the two sides of the external rotor **30**, there are joined the front plate **40** and the rear plate **50** by means of four bolts (not shown), each of which goes through a penetrating passage **32** of the external rotor **30**. Further, four radial projections **31** are formed inwardly in the external rotor **30**. Tops of the radial projections **31** touch the internal rotor **20** so that the external rotor **30** rotates around the internal rotor **20**. The locking pin **81** and a spring **82** are contained in a bore **33** that is formed in one of the radial projections **31**. The bore **33** extends in radial direction of the external rotor **30**. In addition, there is another bore **35** that is formed in another of the radial projections **31**. The bore **35** is symmetrically placed about the axis of the internal rotor **20**. The bore **35** contains the connection pin **91** and a spring **92**. The bore **35** also extends in radial direction of the external rotor **30**.

Each vane **60** has a rounded edge that touches the external rotor **30** in fluid tight manner. Each vane **60** also touches both the plates **40** and **50** in fluid tight manner. The vanes **60** may slide in the vane grooves **20***a* in the radial direction of the internal rotor **20**. Each vane **60** divides each of the pressure chambers R**0** into the advance chamber R**1** and the delay chamber R**2**. The pressure chambers R**0** are formed by the external rotor **30**, the radial projections **31**, the internal rotor **20**, the front plate **40** and the rear plate **50**. As shown in FIGS. **2** through **5**, in order to limit the relative rotation between the internal rotor **20** and the external rotor **30** within a predetermined range, one of the vanes **60** (a vane **60***a* which is described at upper left in FIG. **2**) touches the adjacent radial projections **31***a* at the most advanced and delayed positions. In other words, as shown in FIG. **3**, the most delayed position is achieved when the upper left vane **60***a* touches a delayed side of the radial projection **31***a* due to the expanded delay chambers R**2**. On the contrary, as shown in FIG. **5**, the most advanced position is achieved when the upper left vane **60***a* touches an advanced side of the radial projection **31***a* due to the expanded advance chambers R**1**.

The lock pin **81** is slidably inserted in the bore **33**. The lock pin **81** is pushed toward the internal rotor **20** by a spring **82**. The spring **82** is inserted between the lock pin **81** and a retainer **83**. The retainer **83** is held in the bore **33** by a snap ring **84**.

The connecting pin **91** is slidably inserted in the bore **35**. The connecting pin **91** is pushed toward the internal rotor **20** by the spring **92**. The spring **92** is inserted between the connecting pin **91** and a snap ring **93**.

In the above embodiment, when each of the vanes **60** is in the middle position of the pressure chamber R**0**, the outer end of the fitting hole **29** corresponds with the inner end of the bore **33** such that the top of the locking pin **81** is projected in the fitting hole **29**. In this state, the valve timing of the intake valve is controlled so as to be able to crank the internal combustion engine. Further, when the relative phase between internal rotor **20** with the vanes **60** and the external rotor **30** is from the middle position to the most advanced position, the top of the connecting pin **91** which is disposed in the bore **35** is projected in the groove **28**.

In the above embodiment, the sum of pressures in the advance chamber E**1** balances with the sum of the pressures in the delay chambers R**2** and a rotational counter torque of the pressure chambers R**0** results when predetermined fluid pressures are supplied to the advance chamber R**1** and the delay chamber R**2** after start of the internal combustion engine. When the external rotor **30** is rotated, the rotational counter force is always applied to the vanes **60** toward the most delayed position since the pressure chambers R**0** and the vanes **60** are in the torque transmission path between the external rotor **30** and the internal rotor **20**. In accordance with various conditions of the internal combustion engine, the control valve **100** is controlled to change the balance. The operational fluid (working oil) is supplied to the advance chambers R**1** through the advance passage **12** and passages **23**, and is discharged from the delay chambers R**2** through the passages **26**, the connecting passages **22**, the circle groove **21** and the delay passage **11** when the duty ratio is increased to energize the control valve **100** is energized. The internal rotor **20** with the vanes **60** rotates toward the most advanced position (clockwise direction in FIGS. **2** through **5**) relative to the external rotor **30**, the front plate **40** and the rear plate **50** when the operational fluid is supplied to the advance chambers R**1** and is discharged from the delay chambers R**2**. The relative rotation of the internal rotor **20** with the vanes **60** is limited by the upper left vane **60***a* and the radial projection **31***a* as shown in FIG. **5**. Further, the operational fluid is supplied to the delay chambers R**2** through the passages **26**, the connecting passages **22**, the circle groove **21** and the delay fluid passage **11**, and is discharged from the advance chambers R**1** through advance passage **12** and passages **23** when the duty ratio is decreased to deenergize the control valve **100**. The internal rotor **20** and the vanes **60** rotate toward the most delayed position (counterclockwise direction in FIGS. **2** through **5**) relative to the external rotor **30**, the front plate **40** and the rear plate **50** when the operational fluid is supplied to the delay chambers R**2** and is discharged from the advance chambers R**1**. The relative rotation of the internal rotor **20** with the vanes **60** is also limited by the upper left vane **60***a* and the radial projection **31***a* as shown in FIG. **3**. A predetermined pressure is applied to the fitting hole **29** via the passage **25**, except when the relative phase between the internal rotor **20** with the vanes **60** and the external rotor **30** is in the most delayed position. Due to the applied pressures to the locking pin **81**, the locking pin **81** is moved toward the spring **82** so that the locking pin **81** disengages from the fitting hole **29**. In addition, the operational fluid is also supplied to the connecting groove **28** from the adjacent delay chamber R**2** via the communication groove **27**, when the relative phase between the internal rotor **20** with the vanes **60** and the external rotor **30** is between the most delayed position and the middle position. Due to the applied pressure to the connection pin **91**, the connection pin **91** is moved toward the spring **92** so that the connection pin **91** disengages from the connecting groove **28**. Here, during the above operations, the solenoid **112** of the changeover valve **110** is not energized such that the connecting port **101***a* of the control valve **100** connects to the delay passage **11** via the connection passage **71**.

In the above embodiment, the bore **33** is coaxial to the fitting hole **29** while the vanes **60** are at the middle of the pressure chamber R**0** as shown in FIG. **2**. At this position, the valve timing is set for optimal starting of the internal combustion engine. Therefore, the valve timing may be further delayed up to the most delayed position as shown in FIG. **3**. Thus, for the high-speed operation of the internal combustion engine, the control valve **100** is controlled to further delay the valve timing. The volumetric efficiency can be improved by the inertia of the air intake under high-speed operation of the internal combustion engine so that higher output can be obtained.

When the internal combustion engine is stalled, oil pump P is no longer driven by the internal combustion engine and the solenoid **102** of the control valve **100** is not energized so that the pressure chamber R**0** no longer receives the operational fluid. At this time, neither the pressure in the advance chamber R**1** nor the pressure in the delay chambers R**2** is applied to the vanes **60**, but only the rotational counter force is applied to the vanes **60** toward the most delayed position until the crankshaft **54** of the internal combustion engine is completely stopped. The relative position between the internal rotor **20** and the external rotor **30** is decided according to the relative position therebetween just before the internal combustion engine stalls.

At this time, if the bore **33** is coaxial to the fitting hole **29**, the top portion of the connection pin **91** is projected in the connecting groove **28** so as to prevent the internal rotor **20** with the vanes **60** and the cam shaft **10** from rotating toward the delay side. Accordingly, the top portion of the locking pin **81** is projected in the fitting hole **29** so as to prevent the internal rotor **20** with the vanes **60** from rotating relative to the external rotor **30** as shown in FIG. **2**.

If the bore **33** is positioned at the advance side from the above coaxial position between the bore **33** and the fitting hole **29**, the internal rotor **20** with the vanes **60** and the cam shaft **10** is rotated toward the most delayed position by the above counter force. However, the rotation of the internal rotor **20** with the vanes **60** and the cam shaft **10** is restricted within the length of the communication groove **28**, because the top portion of the connection pin **91** is projected in the communication groove **28**. Due to the restriction of the rotation of the internal rotor **20** with the vanes **60** and the cam shaft **10**, the rotation is stopped at the middle position. Accordingly, the top portion of the locking pin **81** is projected in the fitting hole **29** so as to prevent the internal rotor **20** with the vanes **60** from rotating relative to the external rotor **30** as shown in FIG. **2**.

In the above embodiment, when a starter switch turns on to crank the internal combustion engine, the solenoid **112** of the changeover valve **110** is energized for a predetermined period such that the delay passage **11** connects to the oil pan **105** via the connection passage **71**. Further, when the internal combustion engine cranks, the solenoid **102** of the control valve **100** is not energized such that both the advance chambers R1*a* and the delay chambers R2 are connected to the oil pan **105**. As a result, when the internal combustion engine cranks, the internal rotor **20** with vanes **60** is easy to rotate (vibrate) relative to the external rotor **30** toward both the advance side and the delay side. However, just before the internal combustion engine stalls, if the relative position between the internal rotor **20** and the external rotor **30** is either when the bore **33** and the fitting hole **29** are at the coaxial position or when the bore **33** is positioned at the advance side from the above coaxial position between the bore **33** and the fitting, hole **29**, the top portion of the locking pin **81** is projected in the fitting hole **29** so as to prevent the internal rotor **20** with the vanes **60** from rotating (vibrating) relative to the external rotor **30**.

Just before the internal combustion engine stalls, if the stepped bore **33** is positioned at the delay side from the above coaxial position between the bore **33** and the fitting hole **29**, for example as shown in FIG. **4** or at the most delayed position as shown in FIG. **3**, neither the top portion of the locking pin **81** nor the top portion of the connection pin **91** is projected in the fitting hole **29** or the connecting groove **28**. If the internal combustion engine cranks in this state, the internal rotor **20** with the vanes **60** and the cam shaft **10** starts to rotate relative to the external rotor **30** to the delay direction by a torque variation, which is due to the action upon the cam shaft **10** at the cranking of the internal combustion engine, so as to make it difficult to crank the internal combustion engine. However, in the above embodiment, when a starter switch turns on the internal combustion engine, both the advance chambers R1 and the delay chambers R2 are connected to the oil pan **105** such that the internal rotor **20** with vanes **60** and the cam shaft **10** are easy to rotate (vibrate) relative to the external rotor **30** toward both the advance side and the delay side. When the internal rotor **20** with vanes **60** and the cam shaft **10** rotate (vibrate) relative to the external rotor **30** toward the advance side, the top of the connecting pin **91** is projected into the groove **28**. As a result, the internal rotor **20** with vanes **60** and the cam shaft **10** is prevented from rotating relative to the external rotor **30** toward the delay side from the position where the coaxial position is between the bore **33** and the fitting hole **29**. At the above coaxial position, the top portion of the locking pin **81** is projected into the fitting hole **29** so as to prevent the internal rotor **20** with vanes **60** and the cam shaft **10** from rotating relative to the external rotor **30**.

Therefore, despite the large torque variation, the camshaft **10** and the internal rotor **20** rotate integrally with the external rotor **30** while the internal combustion engine is cranking. The vanes **60** cannot generate any undesirable noise since the vanes **60** are held at the middle of the pressure chamber R**0** when the bore **33** becomes coaxial to the fitting hole **29**.

According to the first embodiment of the present invention, no undesirable noise is generated at all while the internal combustion engine is cranking. Further, volumetric efficiency may be improved by delaying closure of an air-intake valve.

FIG. **6** illustrates another modified version of the first embodiment, which specifically is a modified arrangement of the groove **28**. In FIG. **6**, the same parts in FIGS. **1** through **5** are used with the same numerals of FIGS. **1** through **5**. In this modified construction, there is no communication groove which communicates between the connecting groove **28** and the adjacent delay chamber R2. The connection pin **91** can be moved into the bore **35** against the spring **92** by the centrifugal force of the external rotor **30**. The weight of the connection pin **91** and the biased force of the spring **92** are set up so that the connection pin **91** can be moved into the bore **35** by the centrifugal force of the external rotor **30**, when the rotational speed of the external rotor **30** is a predetermined speed which is less than the rotational speed of the external rotor **30** on the idling period of the internal combustion engine. Further, the above predetermined speed of the external rotor **30** is more than the rotational speed of the external rotor **30** on the cranking period of the internal combustion engine. In the above modified version, when the internal combustion engine is stopped or cranking, the top portion of the connection pin **91** is projected in the groove **28** so as to prevent the internal rotor **20** with the vanes **60** and the cam shaft **10** from rotating relative to the external rotor **30**, such as described in the first embodiment.

In the above embodiments, the bore **35**, the fitting hole **29** and the bore **33** are located in the radial direction of the camshaft **10**, and the locking pin **81** and the connection pin **91** are moved in the same direction. However, this invention may be adapted to another type of valve timing control device. For example, in the arc direction, the thickness of the vanes are heavy and the vanes are integrally provided on the internal rotor. The bore, which is disposed within the locking pin, is located on either one of the end wall of the vane or the front plate (or rear plate). The fitting hole, which is projected in the locking pin, is located on the other one. Accordingly, the moving direction of the locking pin is the same as an axis direction of the cam shaft.

Further, in the above embodiments, the locking pin **81** is moved into the bore **33** by the operational oil which is supplied to the advance chamber R1 via the passage **25**. However, this invention may be adapted to another locking pin. For example, the locking pin is a stepped pin which includes a small diameter portion and a large diameter portion. At the small diameter portion, the operational oil is supplied from either one of the adjacent advance chamber R1 or the adjacent delay chamber R2. At the large diameter portion, the operational oil is supplied from the other chamber. Accordingly, when the operational oil is supplied to either chamber, the locking pin is not projected in the bore.

Further, in the above embodiment, the cam shaft **10** drives the air intake valves of the internal combustion engine. However, this invention may be adapted to another cam shaft that drives the exhaust valves of an internal combustion engine.

What is claimed is:

1. A valve timing control device comprising:

a rotary shaft rotatably assembled within a cylinder head of an internal combustion engine;

a rotational transmitting member mounted around the peripheral surface of the rotary shaft so as to rotate relative thereto within a predetermined range for transmitting a rotational power from a crank shaft;

a vane provided on either of the rotary shaft or the rotational transmitting member;

a pressure chamber formed between the rotary shaft and the rotational transmitting member, and divided by the vane into an advance chamber and a delay chamber;

a first fluid passage for supplying and discharging a fluid to and from the advance chamber;

a second fluid passage for supplying and discharging a fluid to and from the delay chamber;

a locking mechanism for holding the rotary shaft and the rotational transmitting member at a middle position of the predetermined range, when the internal combustion engine starts; and

a controlling mechanism for restricting the rotational transmitting member from rotating around the rotary shaft within a range between the middle position and an end position of the predetermined range.

2. A valve timing control device according to claim 1, wherein the end position is at the most advanced position of the rotary shaft relative to the rotational transmitting member.

3. A valve timing control device according to claim 1, wherein the controlling mechanism includes:

a connecting pin;

a refuge hole formed in either the rotational transmitting member or the rotary shaft for accommodating therein the connecting pin spring-biased toward the other of the rotary shaft and the rotational transmitting member; and

a groove formed in the either the rotary shaft or the rotational transmitting member for fitting therein a top portion of the connecting pin.

4. A valve timing control device according to claim 3, wherein the controlling mechanism further includes a third fluid passage communicating the groove with the pressure chamber such that the connecting pin is moved into the refuge hole.

5. A valve timing control device comprising:

a rotary shaft rotatably assembled within a cylinder head of an internal combustion engine;

a rotational transmitting member mounted around the peripheral surface of the rotary shaft so as to rotate relative thereto within a predetermined range for transmitting a rotational power from a crank shaft;

a vane provided on either one of the rotary shaft and the rotational transmitting member;

a pressure chamber formed between the rotary shaft and the rotational transmitting member, and divided into an advance chamber and a delay chamber by the vane; a first fluid passage for supplying and discharging a fluid to and from the advance chamber;

a second fluid passage for supplying and discharging a fluid to and from the delay chamber;

a locking mechanism for holding the vane in the middle position of the pressure chamber, when the internal combustion engine starts; and

a controlling mechanism for restricting the vane to move within a range between the middle position and an end position of the predetermined range.

6. A valve timing control device according to claim 5, wherein the end position is at the most advanced position of the vane.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,053,139
DATED : April 25, 2000
INVENTOR(S) : Eguchi et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Item [75], please delete "Katzuhiko" and insert -- Katsuhiko --

Signed and Sealed this

Eighteenth Day of September, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer *Acting Director of the United States Patent and Trademark Office*